Report from NASA

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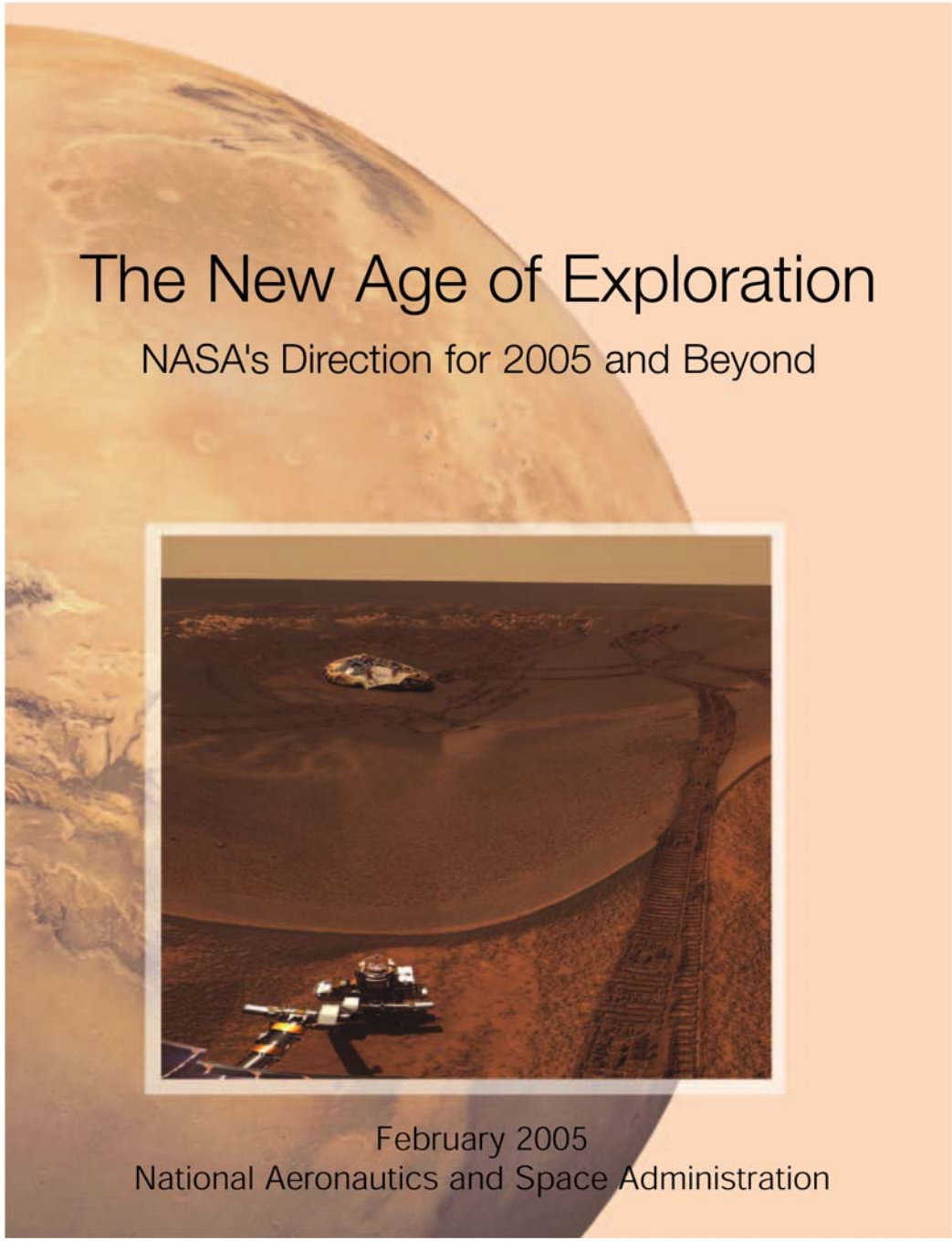
LWS Program Scientist

ILWS WG

April 23, 2005



The first step toward the new NASA Strategic Plan:
Scope of the
Vision for Space Exploration

Available for download from the NASA web site

Sun-Solar System Connection Roadmap: Knowledge for Exploration

<u>Explore the Sun-Earth system</u> to understand the

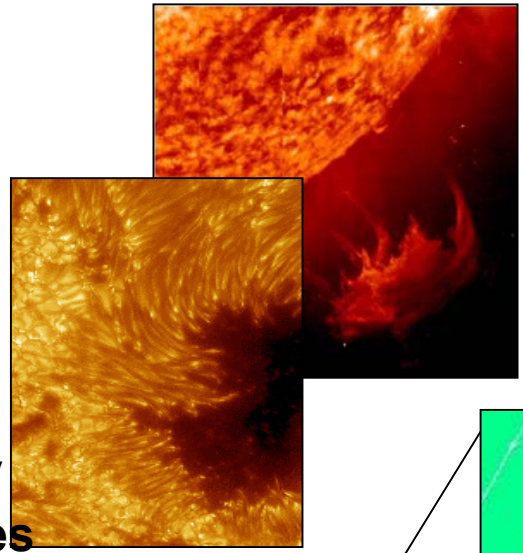
- *Sun and its effects on Earth,*
- *the solar system,*
- *the space environmental conditions that will be experienced by human explorers, and*
- *demonstrate technologies that can improve future operational systems*

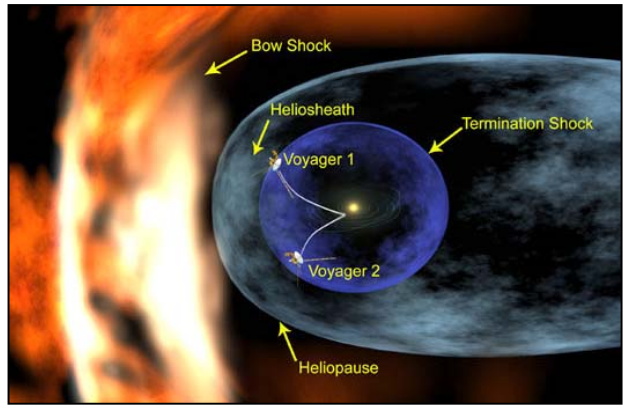
External and Internal Factors

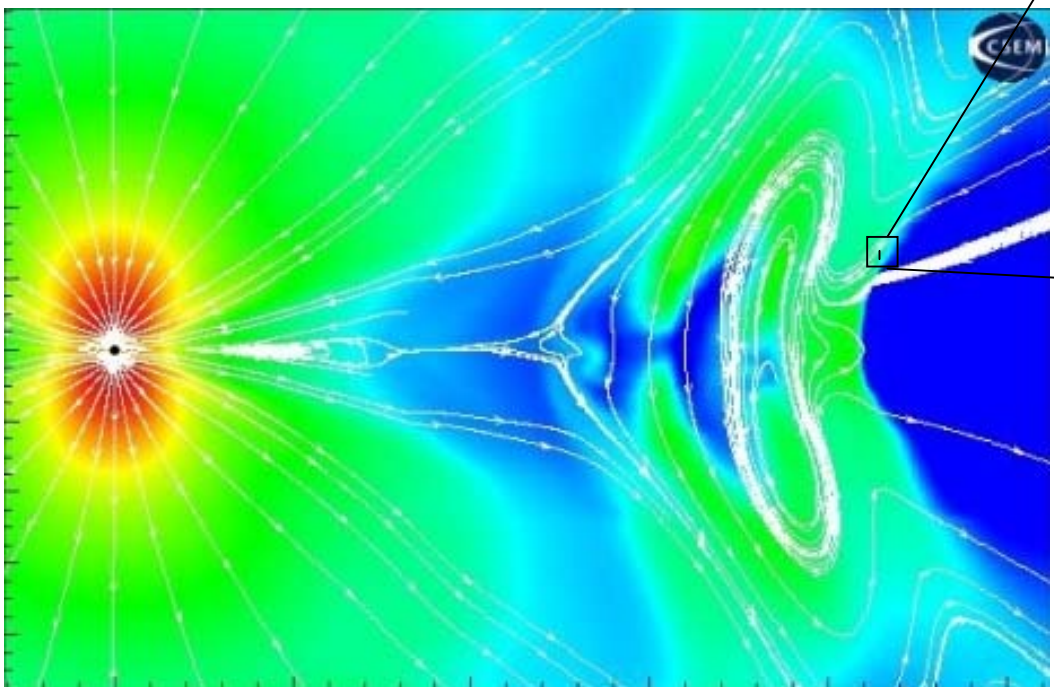
- Our society needs space weather knowledge to function efficiently
- Human beings require space weather predictions to work safely and productively in space
- **We are poised to provide knowledge and predictive understanding of the system**

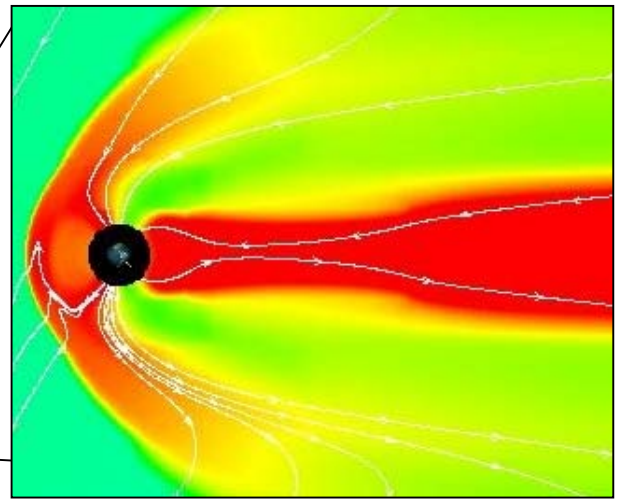
Nature of the Challenge

- A quantitative, predictive understanding of a complex "system of systems"
- Microphysical processes regulate global & interplanetary structures
- Multi-constituent plasmas and complex photochemistry
- Non-linear dynamic responses



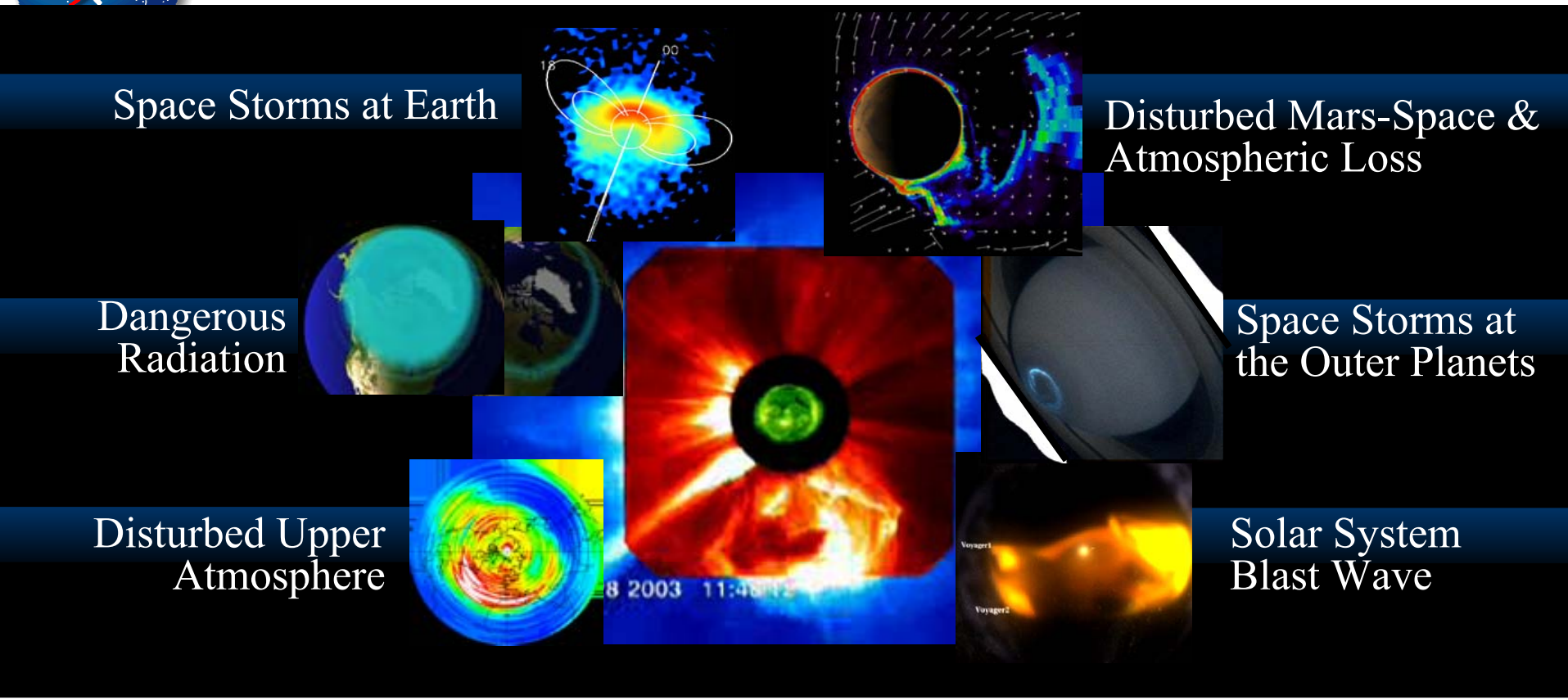






- Integration and synthesis of multi-point observations
- Data assimilative models & theory
- Interdisciplinary communities and tools

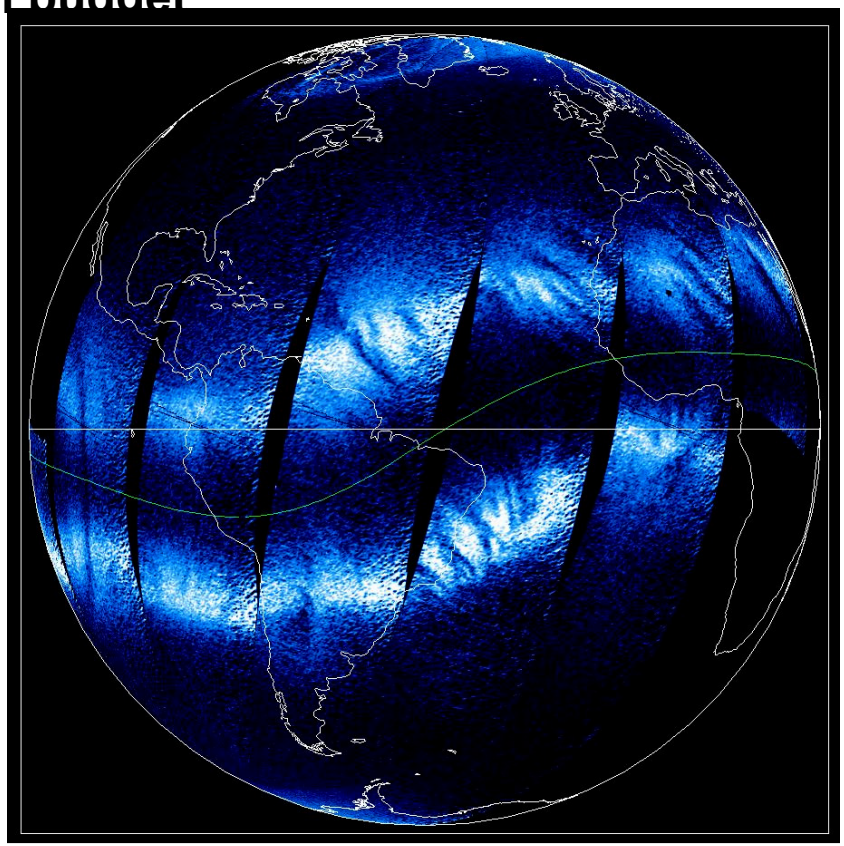
We Have Already Begun!



- **Current Sun-Earth missions provide a prototype "Great Observatory", providing a first look at the system level view and informing the roadmap plan**
- **Theory, modeling, and observational tools now exist or can be developed to yield both transformational knowledge of the Sun-Earth system and provide needed tools and space weather knowledge for human exploration and societal needs**

The 5th Great Observatory

- **World's largest and most expensive plasma physics laboratory**
- **Enabled investigation of the Sun-Solar System "system of systems"**
- **~ $5B investment; ~ $100M/yr annual budget**
- 13 magnetometers
- 9 E-field analyzers
- 15 plasma analyzers
- 31 energetic particle spectrometers
- 4 neutral particle imagers
- 9 RF spectrometers
- 3 visible imagers
- 3 doppler interferometers
- 8 UV and x-ray imag
- ers
- 6 UV and x-ray spectrometers
- 1 IR radiometer
- 4 gamma ray spectrometers

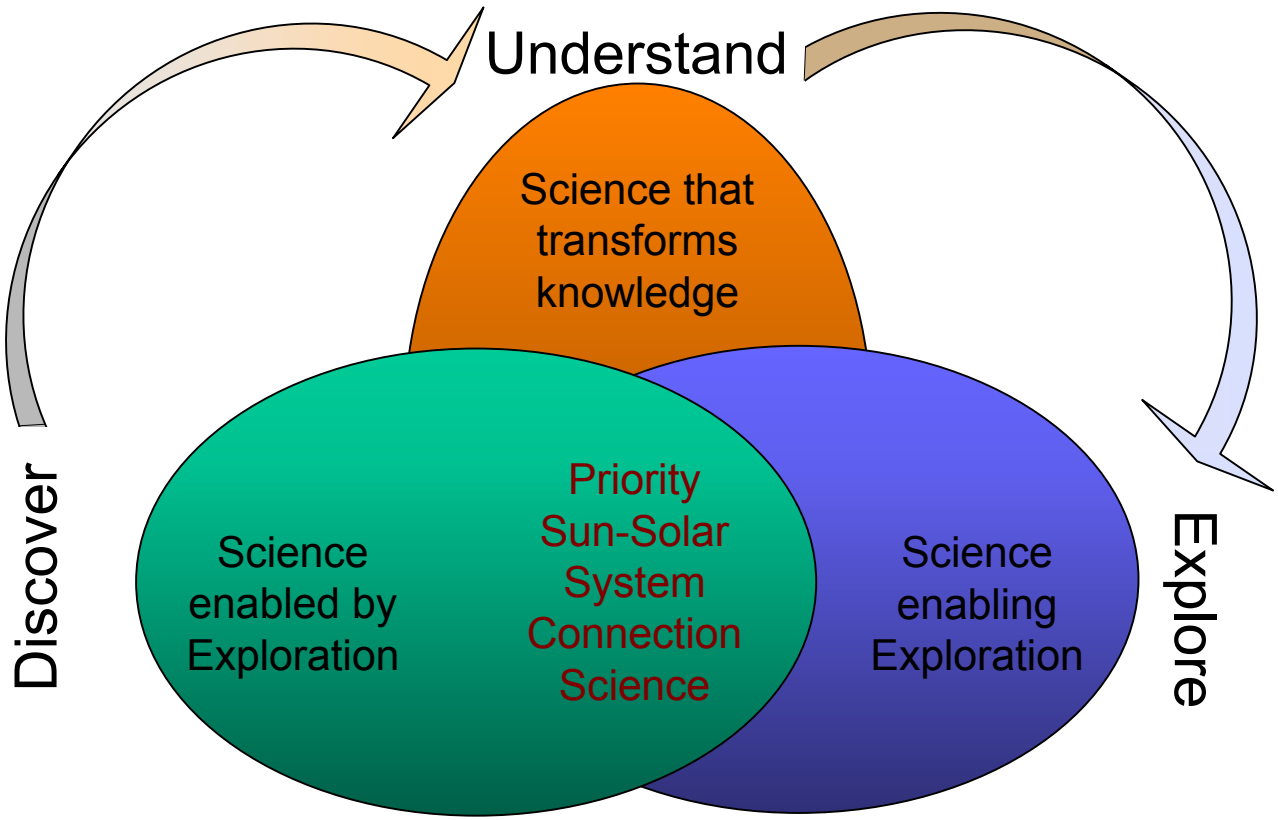


Science for the Vision for Space Exploration

- Science that Flows from Exploration
- Science that Enables Exploration
- Science that Transforms the Knowledge Base
- Science that Addresses National Objectives

Approach to Identify Priority Science Targets

- Predictive capability for safe and productive exploration requires full understanding of a complex system of disparate systems
- Priority goals enable significant progress in three essential areas: Understanding, Exploration, and Discovery
- For example, discovery of processes at the near-Sun region by Solar Probe will provide transformational knowledge of the source of space weather and particle acceleration enabling explorers to work safely and productively beyond the Earth's magnetic shield



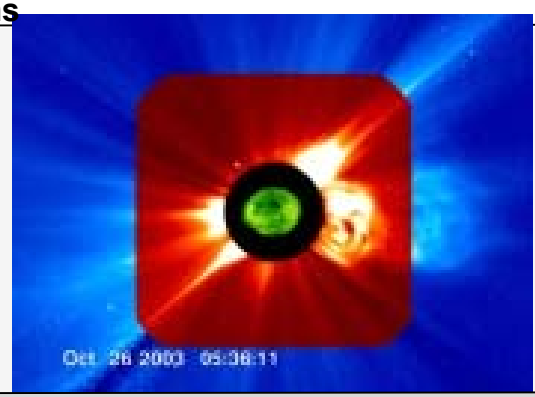
Science that is Vital, Compelling & Urgent

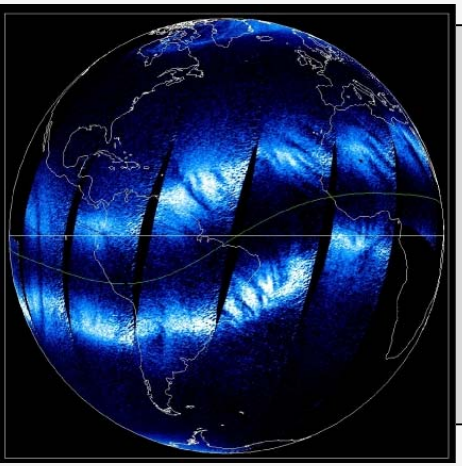
Sun-Solar System Connection Objectives

Agency Strategic Objective: Explore the Sun-Earth system to understand the Sun and its effects on the Earth, the solar system, and the space environmental conditions that will be experienced by human explorers, and demonstrate technologies that can improve future operational systems

Open the Frontier to Space Environment Prediction

Understand the fundamental physical processes of the space environment – from the Sun to Earth, to other planets, and beyond to the interstellar medium



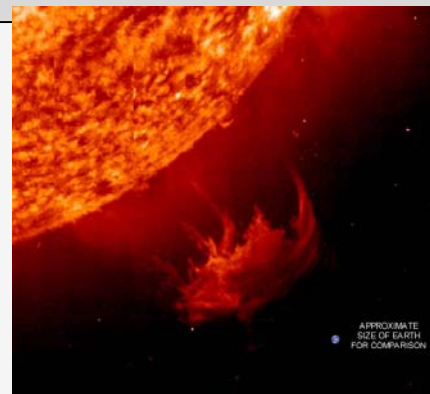


Understand the Nature of Our Home in Space

Understand how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields

Safeguard Our Outward Journey

Maximize the safety and productivity of human and robotic explorers by developing the capability to predict the extreme and dynamic conditions in space



SEC Division Scientific Objectives

SEC Strategic Goal: ***Understand how the Sun, heliosphere, and the planets are connected in a single system.***

- **Explore** the fundamental physical processes of plasma systems in the universe

- **Understand** the changing flow of energy & matter throughout the sun, heliosphere, and planetary environments

- **Define** the origins and societal impacts of variability in the Sun-Earth Connection

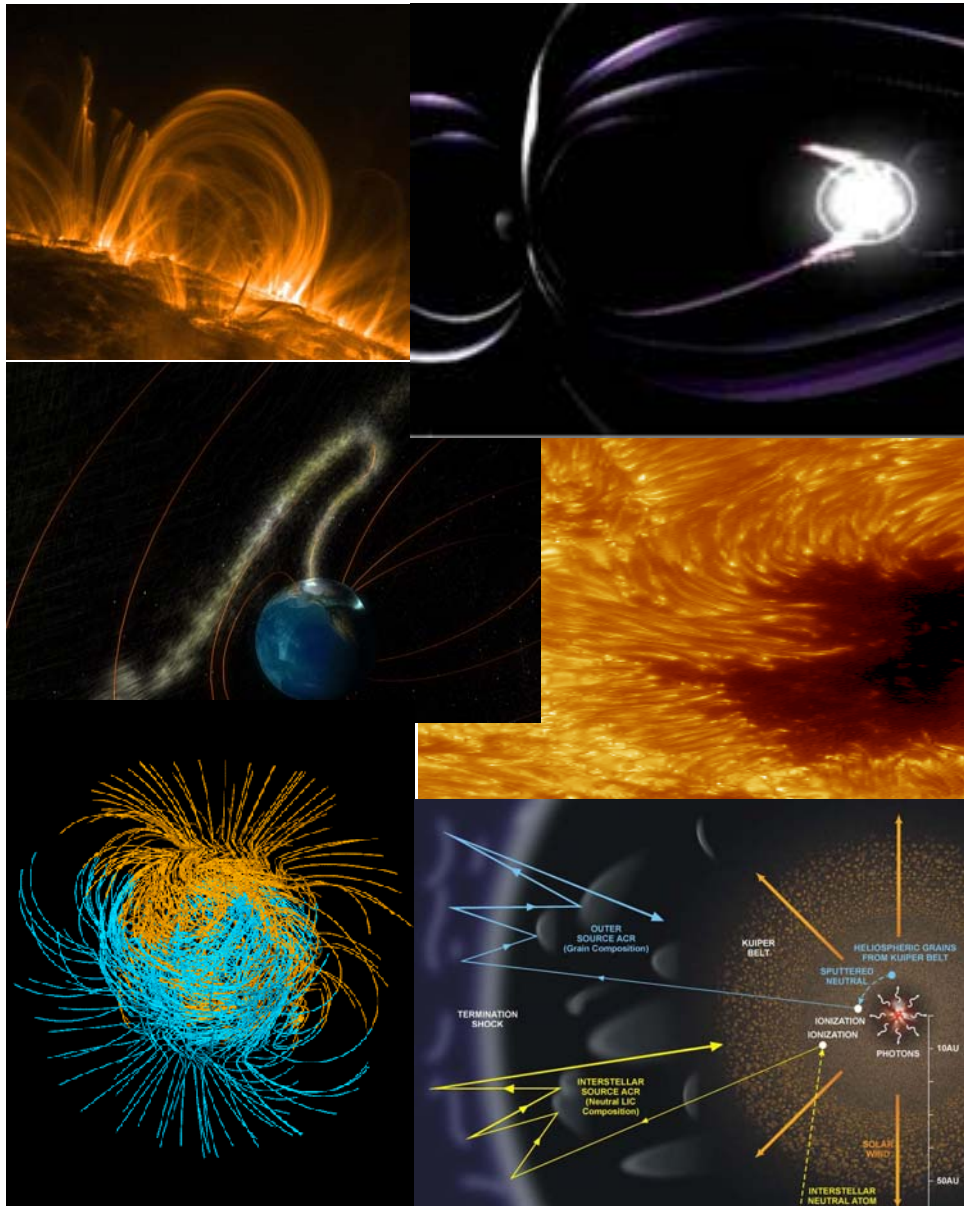
Open the Frontier to Space Weather Prediction

1) Understand magnetic reconnection as revealed in solar flares, coronal mass ejections, and geospace storms

2) Understand the plasma processes that accelerate and transport particles throughout the solar system

3) Understand how nonlinear interactions transfer energy and momentum within planetary upper atmospheres.

4) Determine how solar, stellar, and planetary magnetic dynamos are created and why they vary.



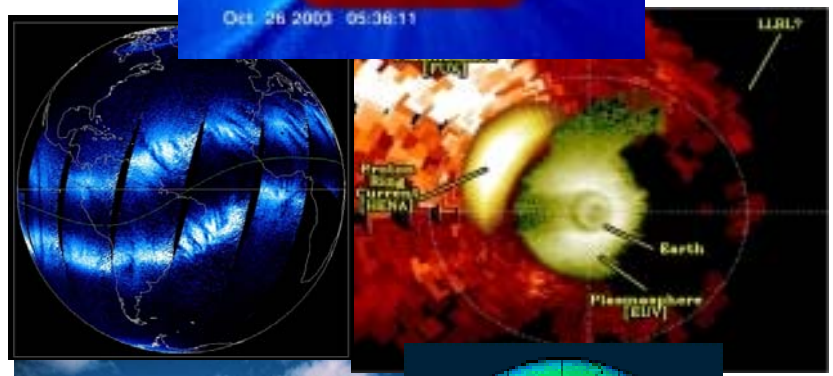
Understand the Nature of our Home in Space

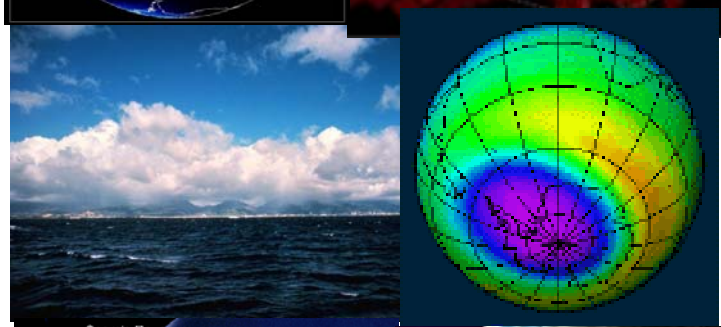
1) Understand the causes and subsequent evolution of activity that affects Earth's space climate and environment

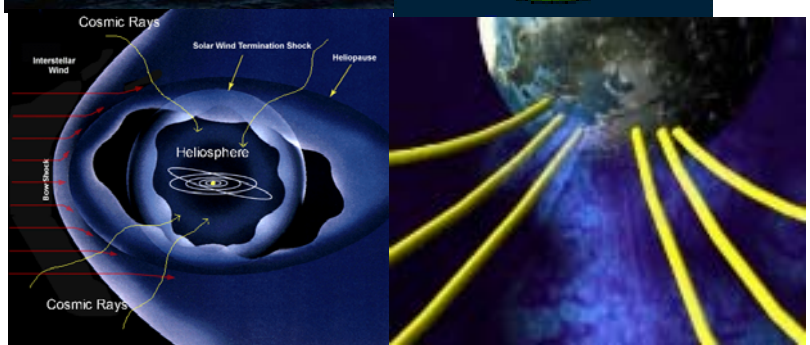
2) Understand changes in the Earth's magnetosphere, ionosphere, and upper atmosphere to enable specification, prediction, and mitigation of their effects

3) Understand the Sun's role as an energy source to the Earth's atmosphere, particularly the role of solar variability in driving climate change

4) Apply our understanding of space plasma physics to the role of stellar activity and magnetic shielding in planetary system evolution and habitability







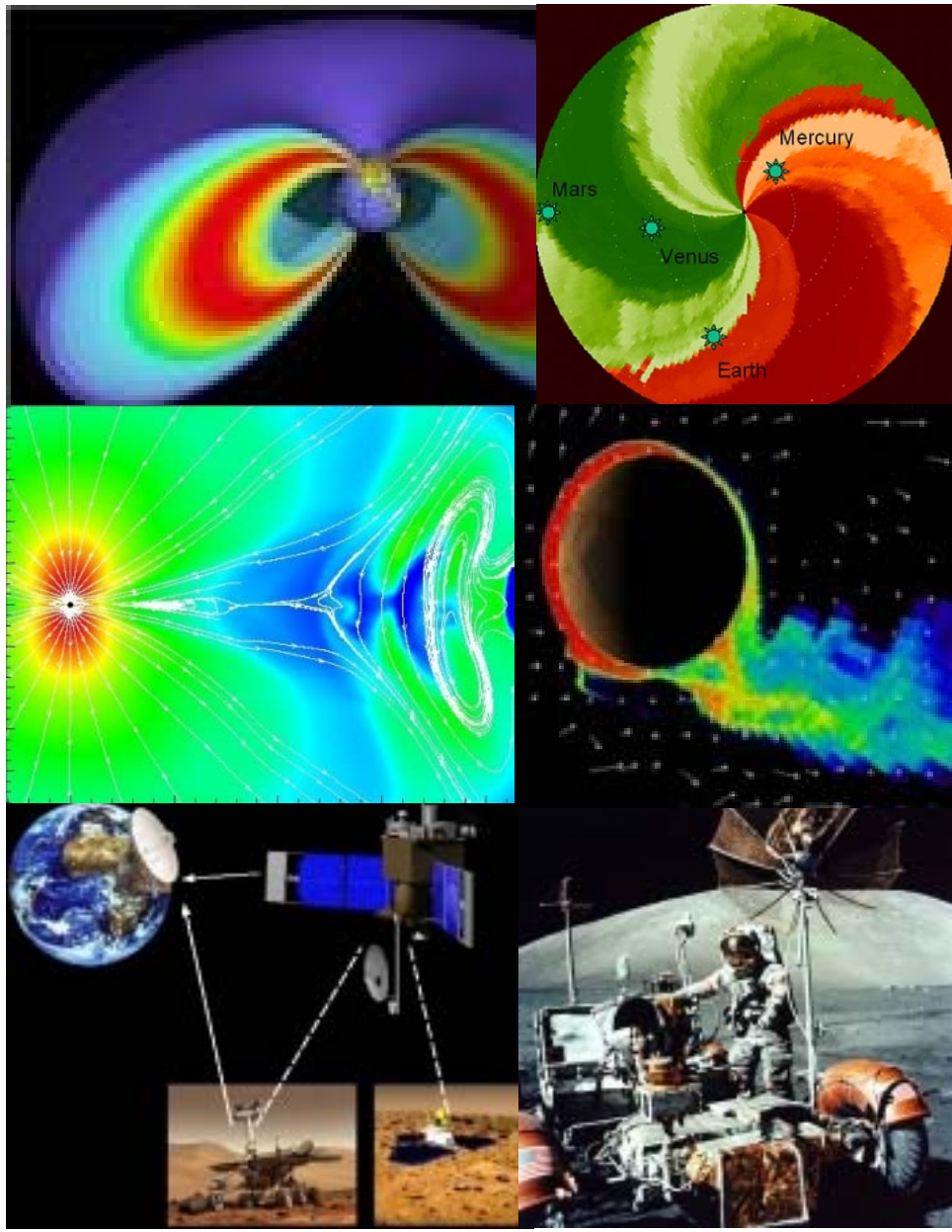
Safeguard our Outward Journey

1) Characterize the variability and extremes of the space environments that will be encountered by human and robotic explorers

2) Develop the capability to predict the origin of solar activity and disturbances associated with potentially hazardous space weather.

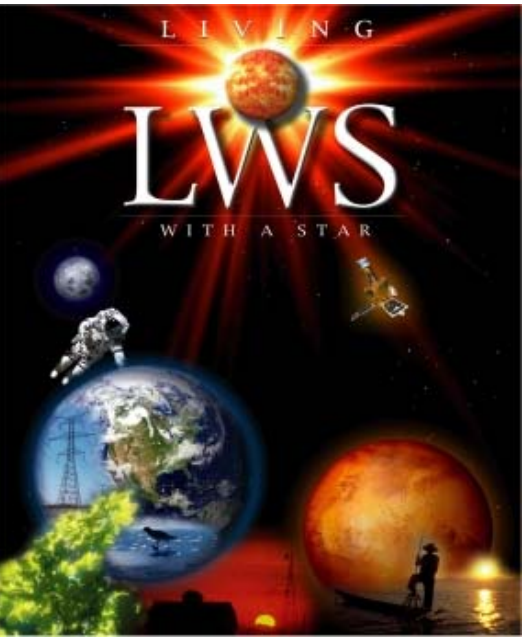
3) Develop the capability to predict the acceleration and propagation of energetic particles in order to enable safe travel for human and robotic explorers

4) Understand how space weather affects planetary environments to minimize risk in exploration activities.



Human Capital and Infrastructure

So that we may develop/maintain U.S. space plasma and space weather prediction / mitigation expertise, it is vital to provide a broad range of competed funding opportunities for the scientific community



Science Investigations:
- Solar Terrestrial Probes (STP)
- Living with a Star (LWS)
- Explorer Program
- Discovery Program
- Sun-Solar System Great Observatory

Research Programs:
- Research and Analysis Grants
- Guest Investigator
- Theory Program
- Targeted Research & Technology
- Project Columbia

Enabling Capabilities:
Sounding Rocket/Balloon Program
Advanced Technology Program
Education and Public Outreach

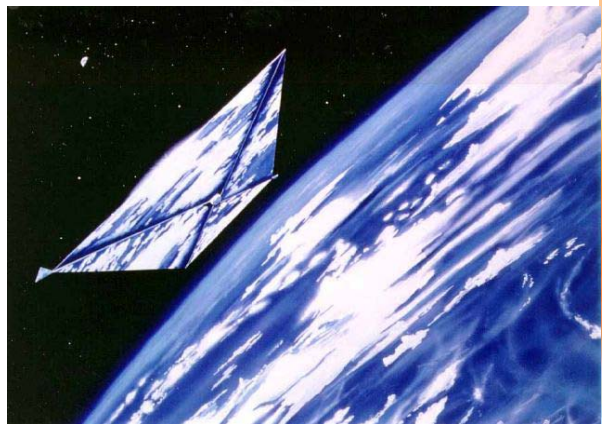
Develop IT, Computing, Modeling and Analysis Infrastructure
- Virtual Observatories

Low Cost Access to Space
- Science, Training, & Instrument Development

E/PO to Attract Workers to Earth-Sun Systems Science

Maintain Multiple Hardware & Modeling Groups
- Strengthen University Involvement in Space Hardware Development
- Facilitate and Exploit Partnerships
- Interagency and International

-**Upgrade DSN to Collect More Data Throughout the Solar System**



External Partnerships

Partnership Forums:

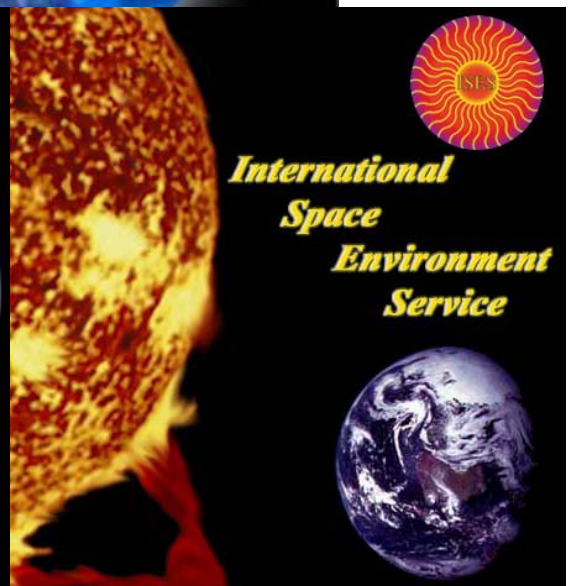
- International Living with a Star
- International Heliophysical Year
- Enabling Space Weather Predictions for the International Space Environment Service
- National Space Weather Program

Current Partnership Missions:

- Ulysses (ESA)
- SoHO (ESA)
- Cluster (ESA)
- Geotail (JAXA)
- Solar-B (JAXA)

Future Partnership Missions:

- Solar Orbiter (ESA)

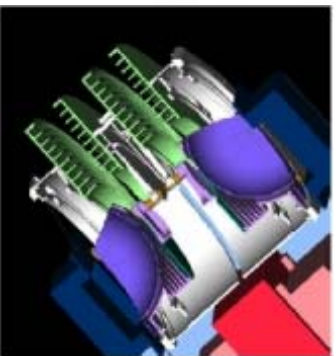


National Partners:

- National Science Foundation
- National Oceanic and Atmospheric Administration
- NOAA Space Environment Center
- Department of Commerce
- Department of Defense
- Department of Transportation
- Department of Energy
- Department of the Interior

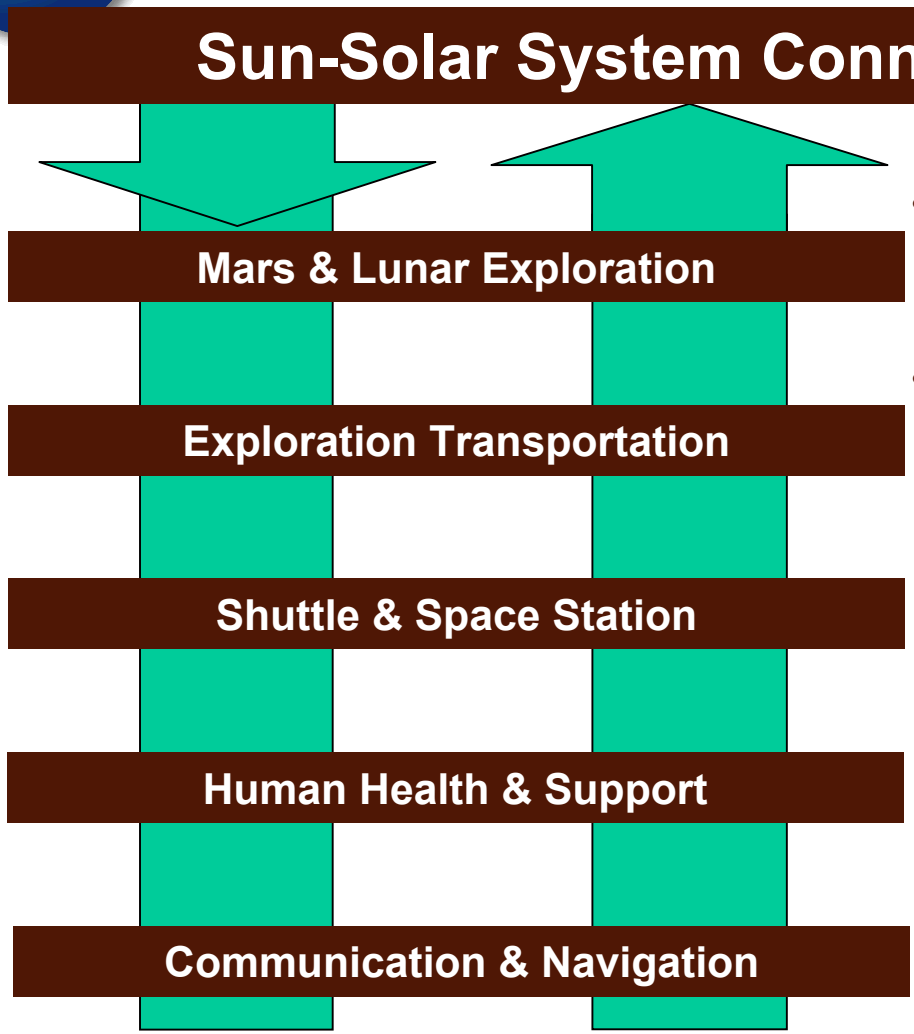
- **International Space Environment Service**
- **NOAA / World Warning Agency in Boulder**

Technology Development



- Answering science questions requires measurements at unique vantage points in and outside the solar system
  - Cost-effective, high-ΔV propulsion
    - CRM-1: High energy power & propulsion—nuclear electric propulsion, RTGs
    - CRM-2: In-space transportation—solar sails
    - CRM-15: Nanotechnology—carbon nanotube membranes for sails
- Resolving space-time ambiguities requires simultaneous in-situ measurements (constellations or sensor webs)
  - Compact, affordable spacecraft via low-power electronics
    - — CRM-3: Advanced telescopes & observatories
  - Low-cost access to space
    - CRM-10: Transformational spaceport
- Return of large data sets from throughout the solar system
  - Next-generation, Deep Space Network
    - CRM-X: Communication and Navigation
- Visualization, analysis and modeling of plasma data
    - CRM-13: Advanced modeling/simulation/analysis
- New measurement techniques – compact, instrumentation suites
  - Next generation of Sun-Solar System instrumentation
    - CRM-11: Scientific instruments & sensors
    - CRM-15: Nanotechnology

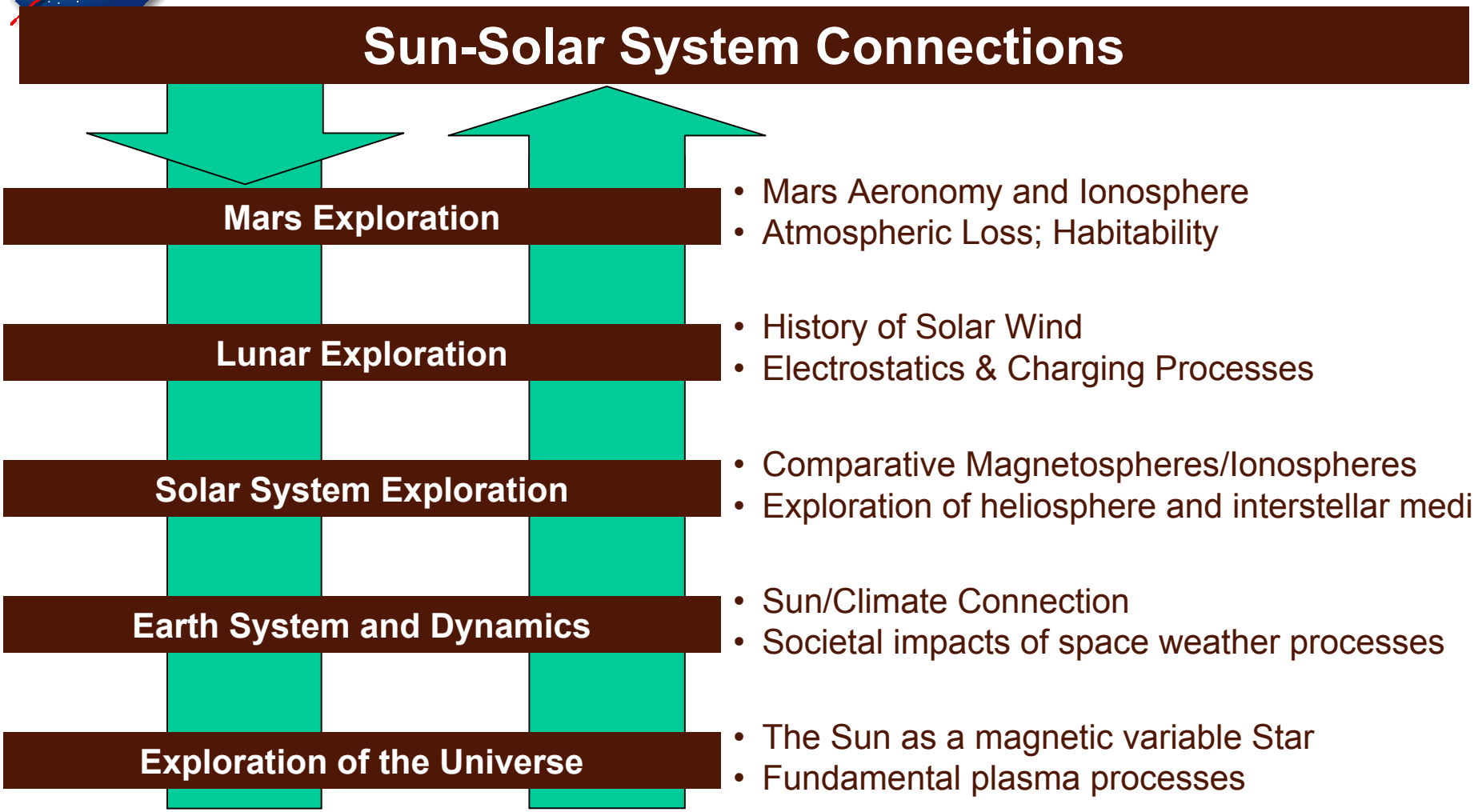
Integration: Human and Robotic Flight



- Space environment **specification** for materials and technology requirements definition.
- **Prediction** of solar activity and its impact on planetary and interplanetary environments as an operational element of Exploration. Examples:
  - presence of penetrating radiation (hazardous to health and microcircuitry);
  - varying ionization/scintillations (interferes with communications and navigation);
  - increased atmospheric scale heights (enhanced frictional drag).

Primary interfaces involve the knowledge of the full range of space environment conditions for requirement specification, prediction, and situational awareness

Integration: Science



Primary interfaces involve understanding of the physical processes associated with the dynamics of space plasmas and electromagnetic fields

SSSC Roadmap Committee

NASA HQ Co-Chair: Al Diaz (NASA HQ Science Mission Directorate)
Center Co-chair: Franco Einaudi (NASA GSFC)
Center Co-chair: Thomas Moore (NASA GSFC)
External Co-chair: Timothy Killeen (National Center for Atmospheric Research)
Directorate Coordinator: Barbara Giles (NASA HQ Science Mission Directorate)
APIO Coordinator: Azita Valinia (NASA GSFC)

Committee Members:
Scott Denning (Colorado State University)
Jeffrey Forbes (Univ of Colorado)
Stephen Fuselier (Lockheed Martin)
William Gibson (Southwest Research Institute)
Don Hassler (Southwest Research Institute)
Todd Hoeksema (Stanford Univ.)
Craig Kletzing (Univ. Of Iowa)
Edward Lu (NASA/JSC)
Victor Pizzo (NOAA)
James Russell (Hampton University)
James Slavin (NASA GSFC)
Michelle Thomsen (LANL)
Warren Wiscombe (NASA GSFC)

Ex Officio members:
Donald Anderson (Science Mission Directorate)
Dick Fisher (Science Mission Directorate)
Rosamond Kinzler (American Museum of Natural History)
Mark Weyland (Space Radiation Analysis Group, JSC)
Michael Wargo (Exploration Systems Mission Directorate)
Al Shafer (Office of the Secretary of Defense)

Systems Engineers:
John Azzolini (GSFC)
Tim Van Sant (GSFC)

SSSC Roadmap Activities

• **NRC update to Space Physics Decadal Survey**	**Sep. 2004**	
• **Solar Sail technology workshop**	**Sep. 28-29, 2004**	
• **Roadmap working team meeting**	**Oct. 5-6, 2004**	
• **Advisory Committee review of progress**	**Nov. 3-5, 2004**	
• **Community-led imaging technology workshop**	**Nov. 9-10, 2004**	
• **Community-wide roadmap workshop**	**Nov. 16-17, 2004**	
• **Roadmap working team meeting**	**Nov. 18-19, 2004**	
• **Roadmap working team meeting**	**Jan. 19-21, 2005**	
• **Update to NRC Space Studies Board CSSP**	**Feb. 8, 2005**	
• SRM#10 committee meeting #1	Feb. 10-11, 2005	First Draft
• **Half-day bilateral meetings with other US Government agencies**	**Late Feb/Early March**	
• **Advisory Committee review of progress**	**February 28-March 2**	
• **SMD International Strategic Conference on Roadmaps**	**March 8-10**	
• SRM #10 committee meeting #2	March 15-16	
• **Roadmap working team meeting**	**March 16-18**	Second Draft
• **Advisory Committee review of progress**	**March 30-April 1**	
• SRM #10 committee teleconference	April 11	
• **Roadmap working team meeting**	**May 9-10**	
• SRM #10 committee meeting #3	~May 12-13	Final Draft
• **Roadmap review by the National Academy**	**June 1**	

SSSC –Roadmap Information

Most documentation and communication is open and available:

- http://sec.gsfc.nasa.gov/roadmap **for general information**
- http://sun.stanford.edu/roadmap **for working documents**
- http://www.nasa.gov/about/strategic_roadmaps.html **for NASA-level strategic planning documents**
- roadmap@sun.stanford.edu**, email address to reach all roadmap members**
- http://ssscroadmap.blogspot.com **archive of email exchanges**

SDO Mission/Project Overview

- **In-house implementation at Goddard Space Flight Center (GSFC) including:**
  - In-house spacecraft build & Observatory integration/testing
  - In-house Ground System development/management & Mission Operations.
  - Management of instrument contracts with Principal Investigators responsible for development of their instrument & Science Operations Center (SOC).
  - Single ground station at White Sands with distributed SOCs.
- **Launch from KSC into GEO-Transfer Orbit (GTO), circularize to GEO-Sync Orbit, inclined 28.5 degrees with semiannual eclipse seasons.**
- **5 year prime lifetime, solar-tracking with low jitter; continuous high data rate (130 Mbps)**
- **Non-Science driven Level 1 requirements:**
  - 3200 kg SDO Observatory mass allocation with remaining LV lift capability reserved for potential secondary payload.
  - GTO insertion transfer orbit with a minimum perigee of 300 km for possible secondary GTO payload options.

What SDO Will Do…

In order to meet the needs of the Living With a Star program and determine the drivers and diagnostics of solar activity and variability that affect Earth and humanity, the Solar Dynamics Observatory must:

- Provide *nearly continuous* coverage of solar activity
- Observe all of the solar regimes in which the activity occurs (interior, photosphere, atmosphere)
- Collect necessary data on the types of phenomena that impact Earth, near-Earth space, and humanity
- Cover all of the relevant timescales of solar variability (seconds to years)

SDO Significant Issues

- SDO had to pay 20.8 M in earmark money in FY05
- This is going to change the launch date of SDO
- Initial estimate suggests a 4 month slip to 8/2008

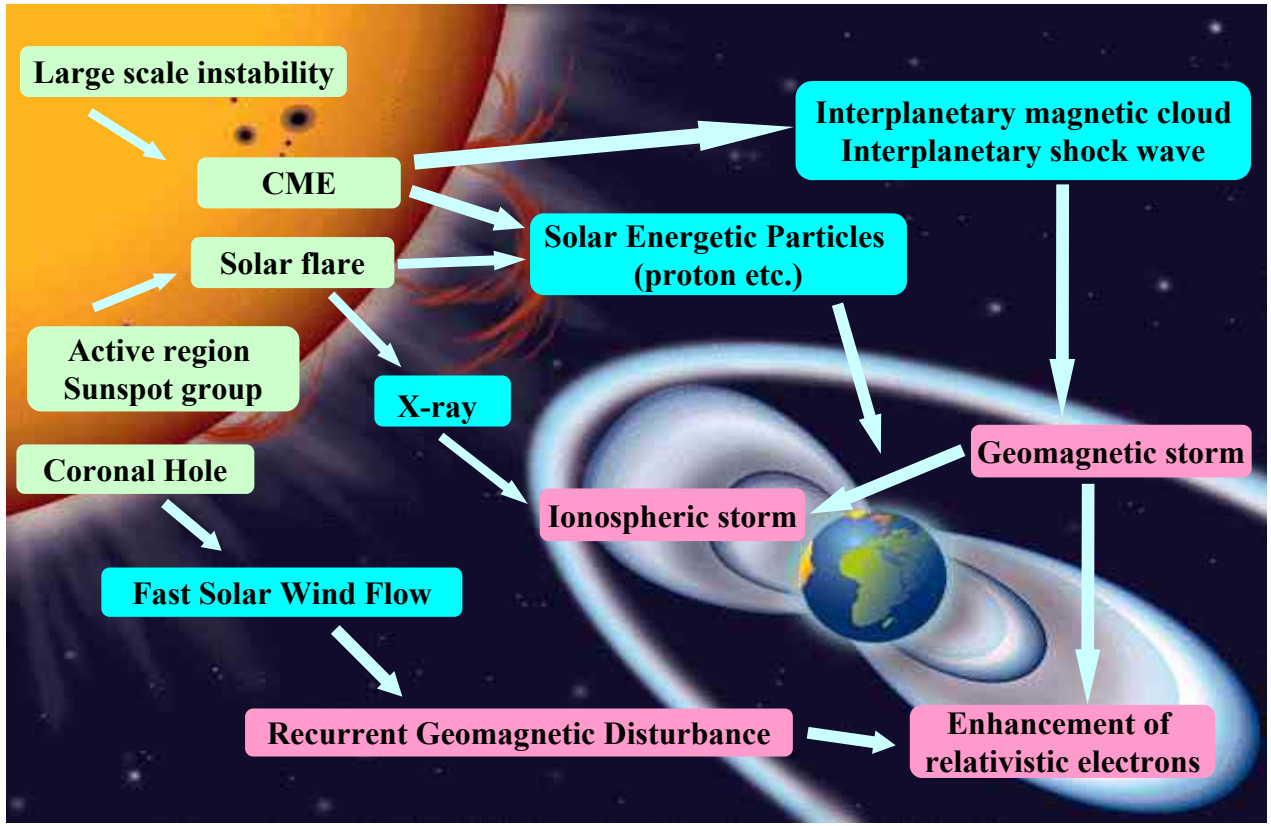
Opportunity for Participation

The National Aeronautics and Space Administration (NASA) intends to release an Announcement of Opportunity (AO) for Radiation Belt Storm Probes (RBSP) Investigations in June 2005.

The RBSP mission will require a variety of instruments to be carried on a two identical NASA-supplied spacecraft to be launched in the early 2011 with a prime mission of two years.

-Launch date for ITSP will be decided after the strategic planning process is completed.

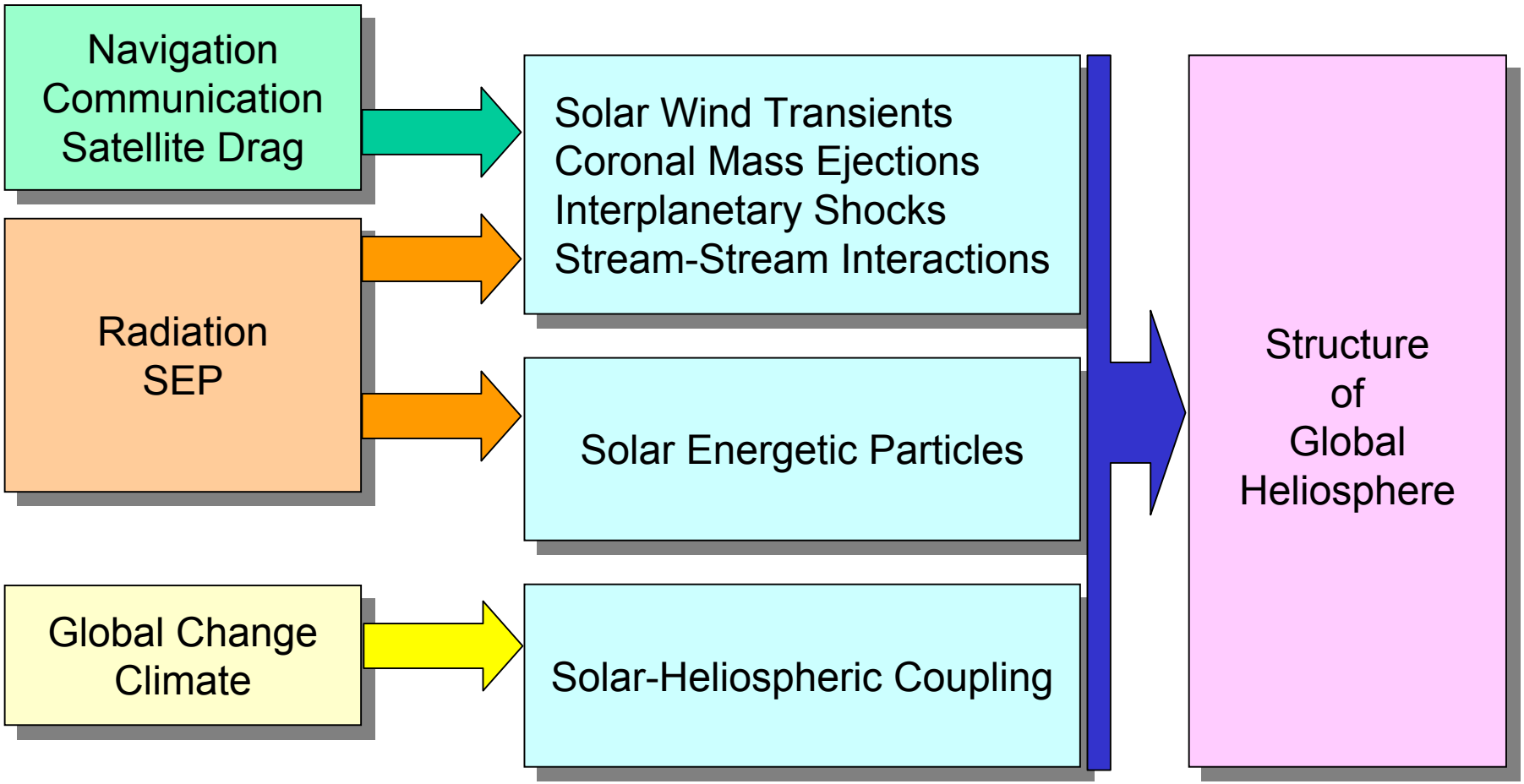
Solar Sentinels: Primary Objective



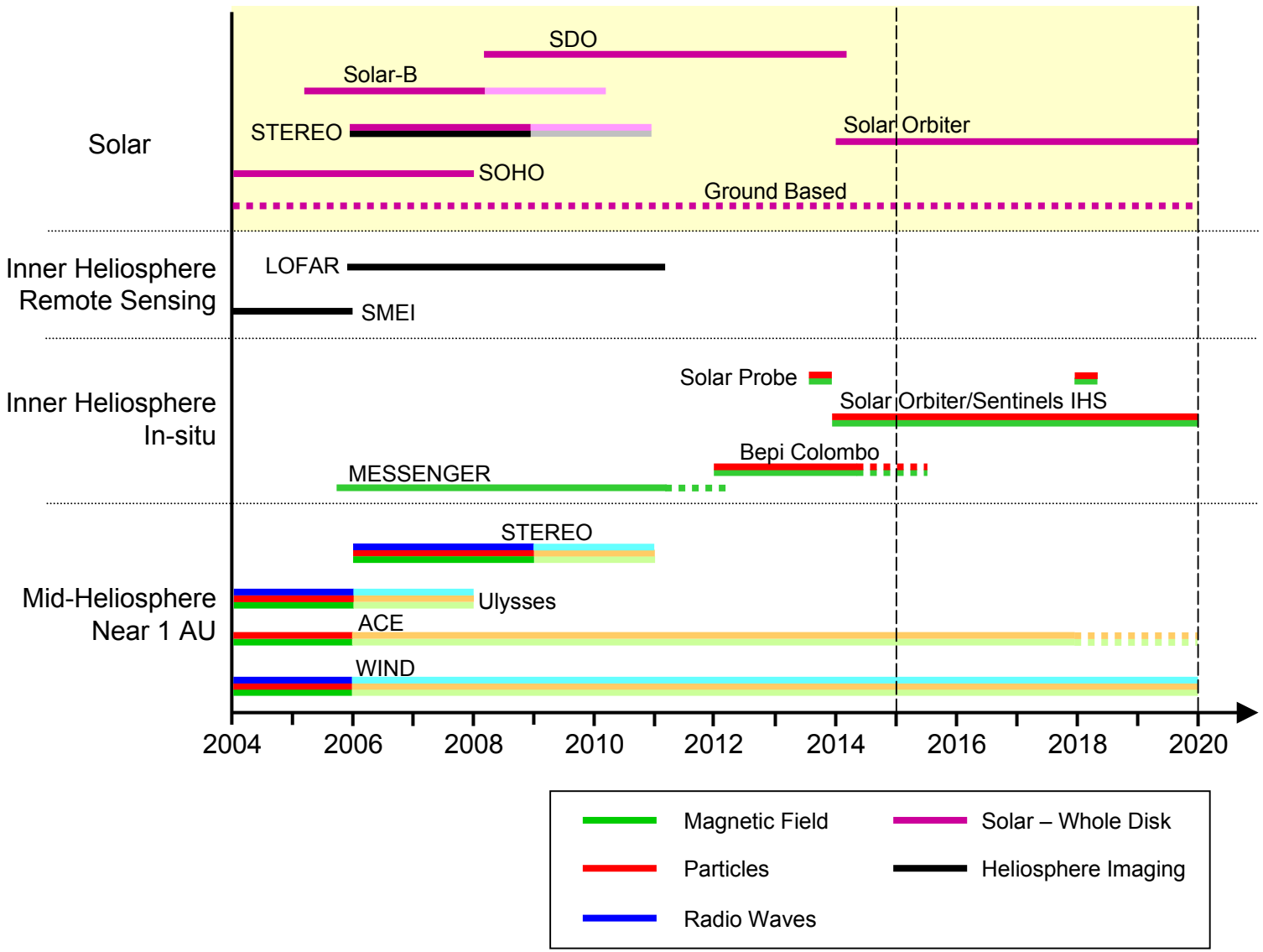
Discover, understand and model the connection between solar phenomena and geospace disturbances.

Societal Impacts

Sentinels Science Focus Areas

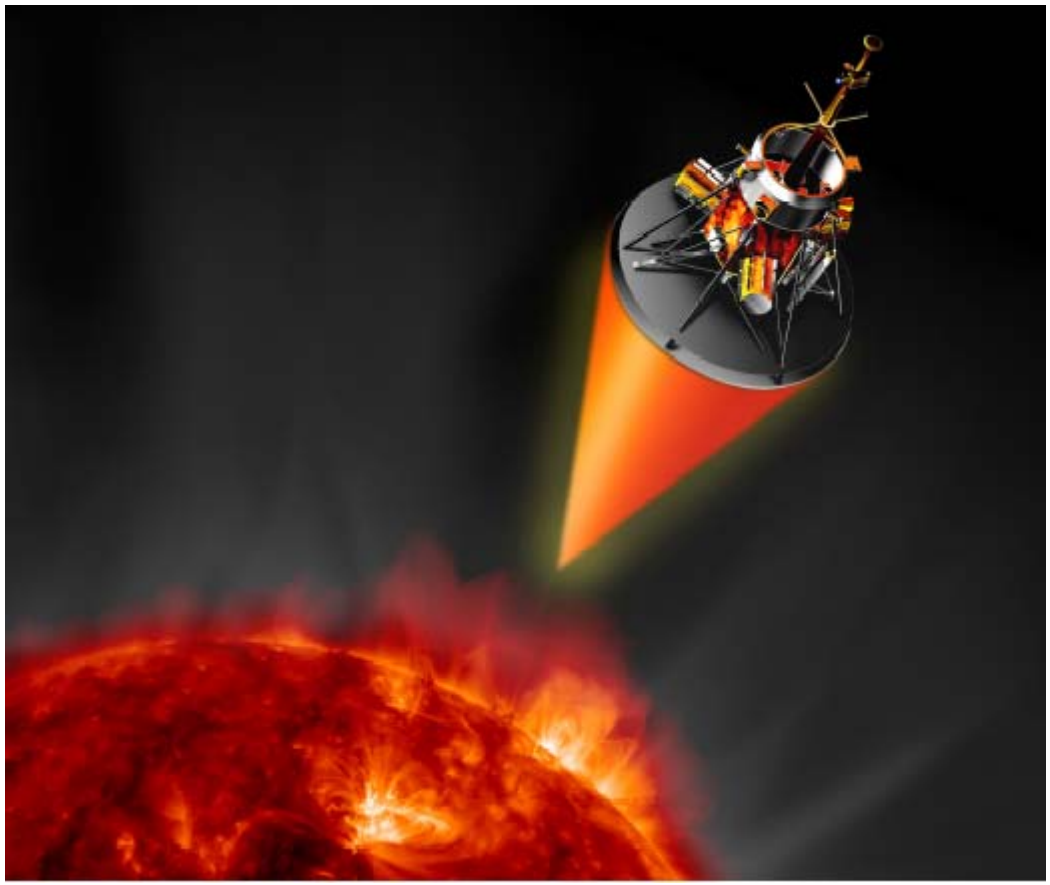


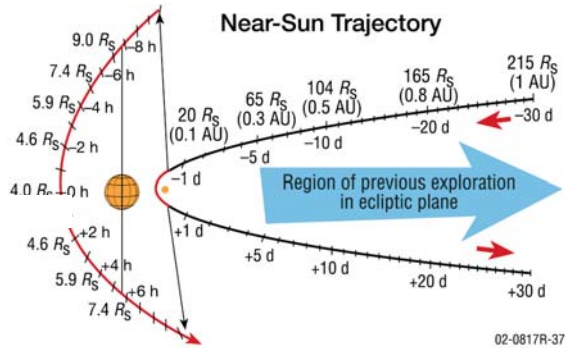
Mission Timelines



Report due in Spring of 2005

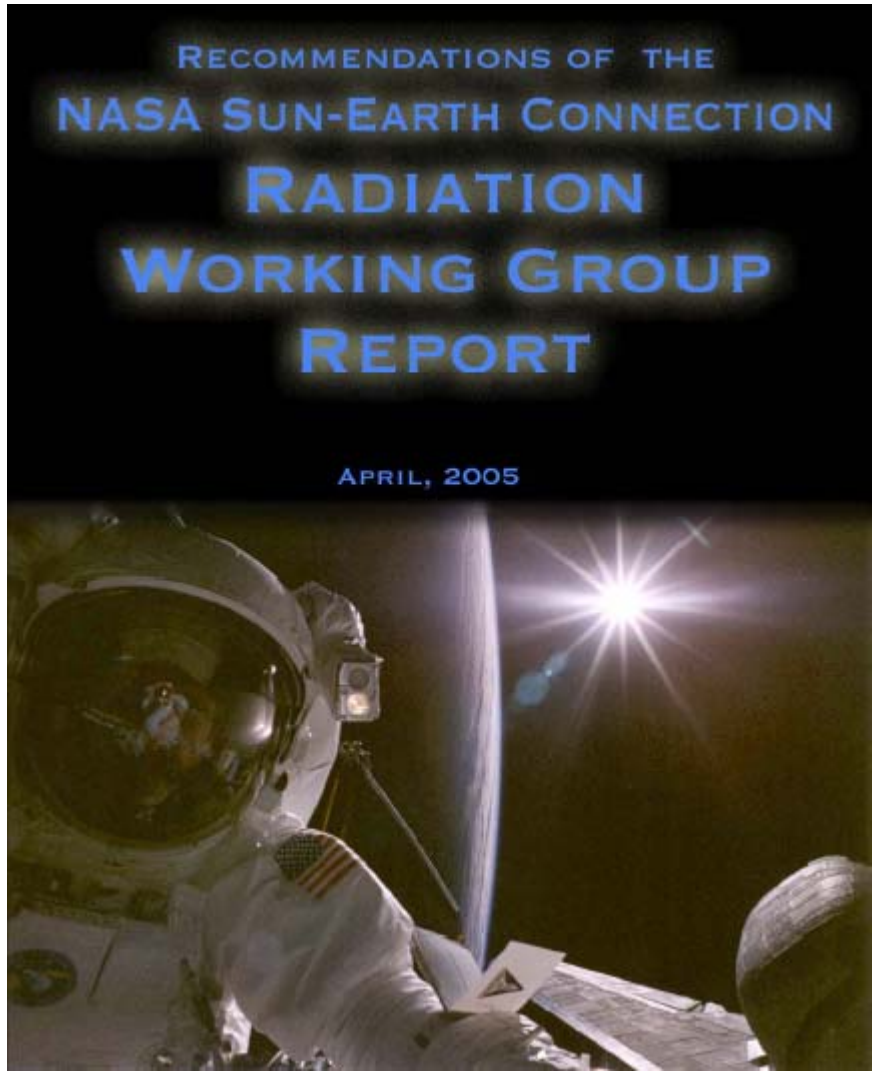
Our First Visit to a Star





Report of the Solar Probe Science and Technology Definition Team

Task group report on radiation environment and exploration will be available in Spring 2005

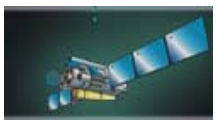


Executive summary is available at: lwsscience.gsfc.nasa.gov

Solar Terrestrial Probes Program Missions and Program Content

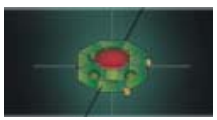
- **STP Program Missions**

--TIMED: Timed is used to study the effect of solar magnetic variation on the Earth's Upper atmosphere and has recently been successful in measuring upper atmospheric chemical processes driven by variation in solar UV radiance. (TIMED is in an extended mission phase)

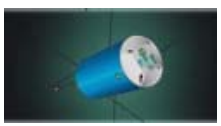


-- **SOLAR-B** will measure the ate of magnetic flux in the Sun's atmosphere as well as UV and X-radiation to increase understanding for the source of variations of the solar magnetic field which influence the Earth and the interplanetary regions of the solar system. (Solar B will launch on a Japanese rocket in 2006)

– **STEREO** Two spacecraft will measure solar wind and coronal mass ejections in three dimensions and use the data to develop predicative capabilities for solar events and space weather effects



–- **Magnetospheric Multi-Scale (MMS)** Mission Four spacecraft will measure the Earth's magnetospheric plasma and use the data to verify the theoretical description of how plasma is transported, density is built up, and the role and nature of turbulence in the magnetosphere. The process of magnetic reconnection, the means by which magnetic energy is converted to radiation and mechanical energy, is a topic of investigation for this mission.



–- **Geospace Electrodyanmic Connections** (**GEC)** - Four spacecraft will measure particles and fields at the boundary of the magnetosphere and ionosphere to identify how energy exchange between the atmospheric regions changes with time.

–_ **Magnetopheric Constellation (MC)** 30-50 nanosatellites will be used to measure the three dimensional variations in the Earth's plasma and fields to find out how events in this region affect the Earth's magnetosphere and radiation environment.

Mission Description

Mission Objectives: **2-year mission to measure the causes and mechanisms of CME initiation and characterization of their propagation through the heliosphere. 1-year extended data analysis.**

Organizations: **NASA GSFC, JHU/APL, Naval Research Laboratory, University of California at Berkeley, University of New Hampshire, University of Minnesota, Observatoire de Paris with significant hardware contribution from Europe**

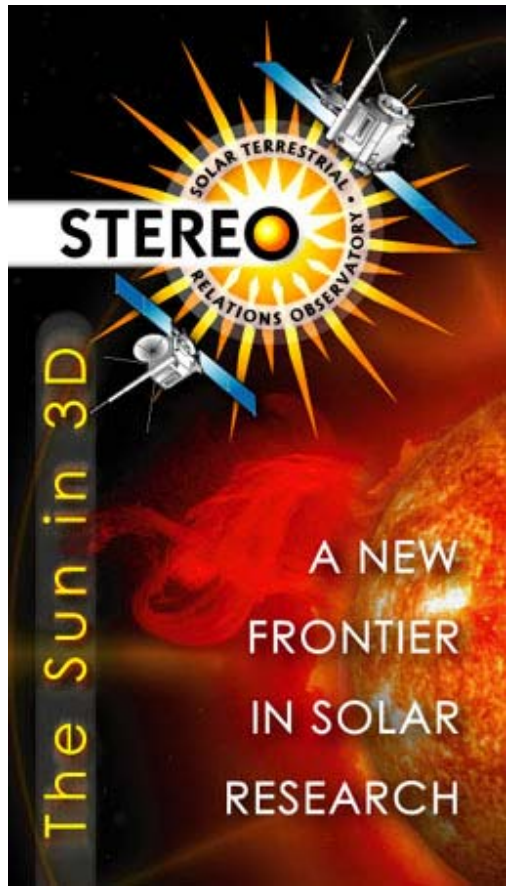
Mission Description: **Two functionally identical spacecraft in heliocentric orbits at 1 AU (22°/yr drift from Earth orbit leading/lagging configuration).**

Each Observatory:

Volume:	1.2 w x 2.0 l x 1.5 h meters
Dry Mass:	A: 535 kg B: 561 kg
Power:	509 W (EOL)

Launch: **To be launched from KSC on a Delta 2925-10L.**

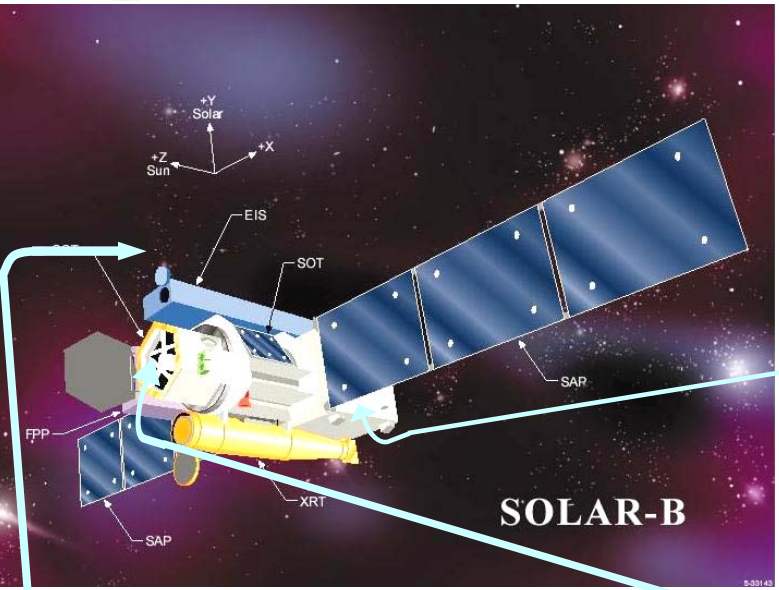
Website: **http://stereo.gsfc.nasa.gov**



Solar-B

Objective: Measure the sun's magnetic field and ultraviolet/s-ray radiation and use the data to increase the understanding of the sources of solar variability.

Launch: Sept 2006 from Kagoshima, Japan
Japanese spacecraft and M-V launch vehicle
Orbit: Sun-synchronous LEO (600-km circular)



X-ray Telescope (XRT)

- **SAO – telescope, filters, mechanisms, instrument integration**
- **Japan – camera & electronics**

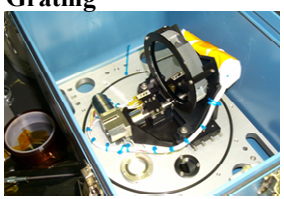
Extreme Ultraviolet Imaging Spectrometer (EIS)

- **NRL – optics and mechanisms**
- **UK – structure, camera, electronics, instrument integration**

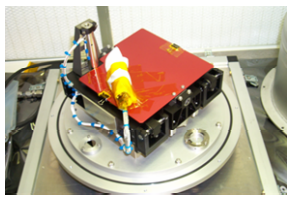
Focal Plane Package (FPP)

- **LM – instrument package**
- **Japan – Solar Optical Telescope, instrument integration**

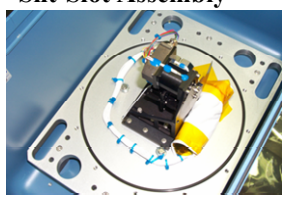
Grating



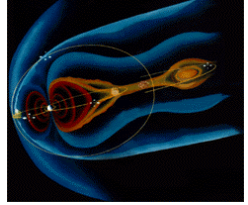
Mirror



Slit-Slot Assembly



Project Description: Magnetospheric MultiScale (MMS)

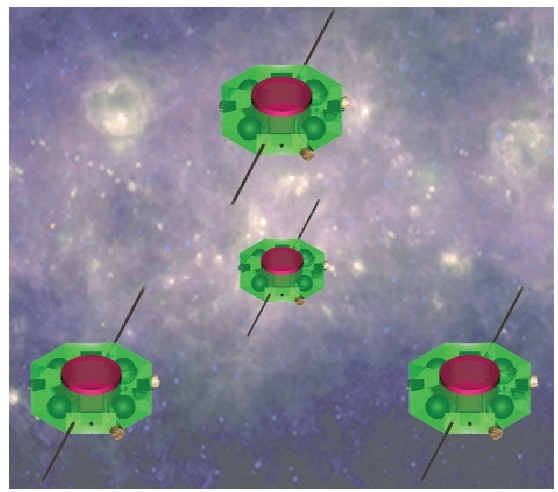


Mission Objectives: 2-yr mission to explore and understand the fundamental plasma physics processes of reconnection, particle acceleration, and turbulence on the micro- and mesoscale in the Earth's magnetosphere.

Organizations: GSFC: Project Management, Systems Engineering, Mission Ops
TBD: Instrument Science Suite Team Principal Investigator
TBD: RSDO Vender
TBD: Ranging System

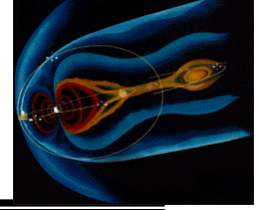
Mission Description:

- 4 spin-stabilized spacecrafts
- 4 suites of identical instruments: electric field, energetic particles, hot plasma & magnetometer
- Inter-spacecraft ranging system
- Tetrahedron constellation
- 4 mission orbit phases (elliptical: perigee 1.2 R_E)
  - Phase 1 apogee 12 R_E 9 months
  - Phase 2 apogee 20-30 R_E 3 months
  - Phase 3 Lunar assist maneuver
  - Phase 4 apogee 40 R_E 11 months (perigee 10 R_E)
- Observatory resources (conceptual)
  - Mass ~300kg
  - Power ~130W
  - Data rate ~2Gbit/day
  - Dimensions ~2m across flats ~0.9m high



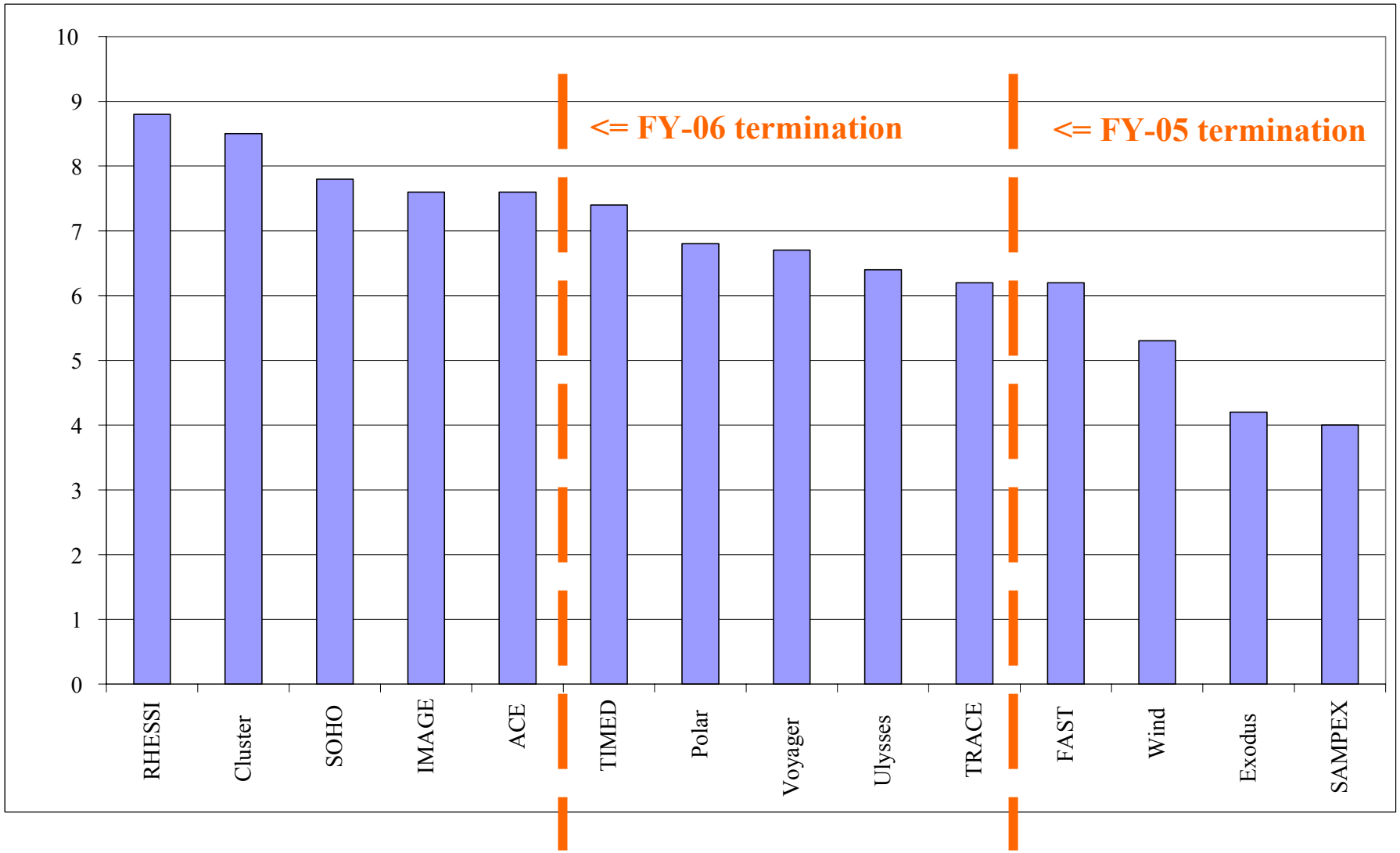
Launch: UNDER REVIEW To be launched from KSC on a Delta II (heavy) in 1/10
Web Site: stp.gsfc.nasa.gov

MMS Significant Progress



- **Budget Status**
  - 10 M available in FY05
- **In the near term NASA will announce the down select from Phase A to Phase B**

The 'Grades' Average of 'Science Value' and Contribution to the Roadmap



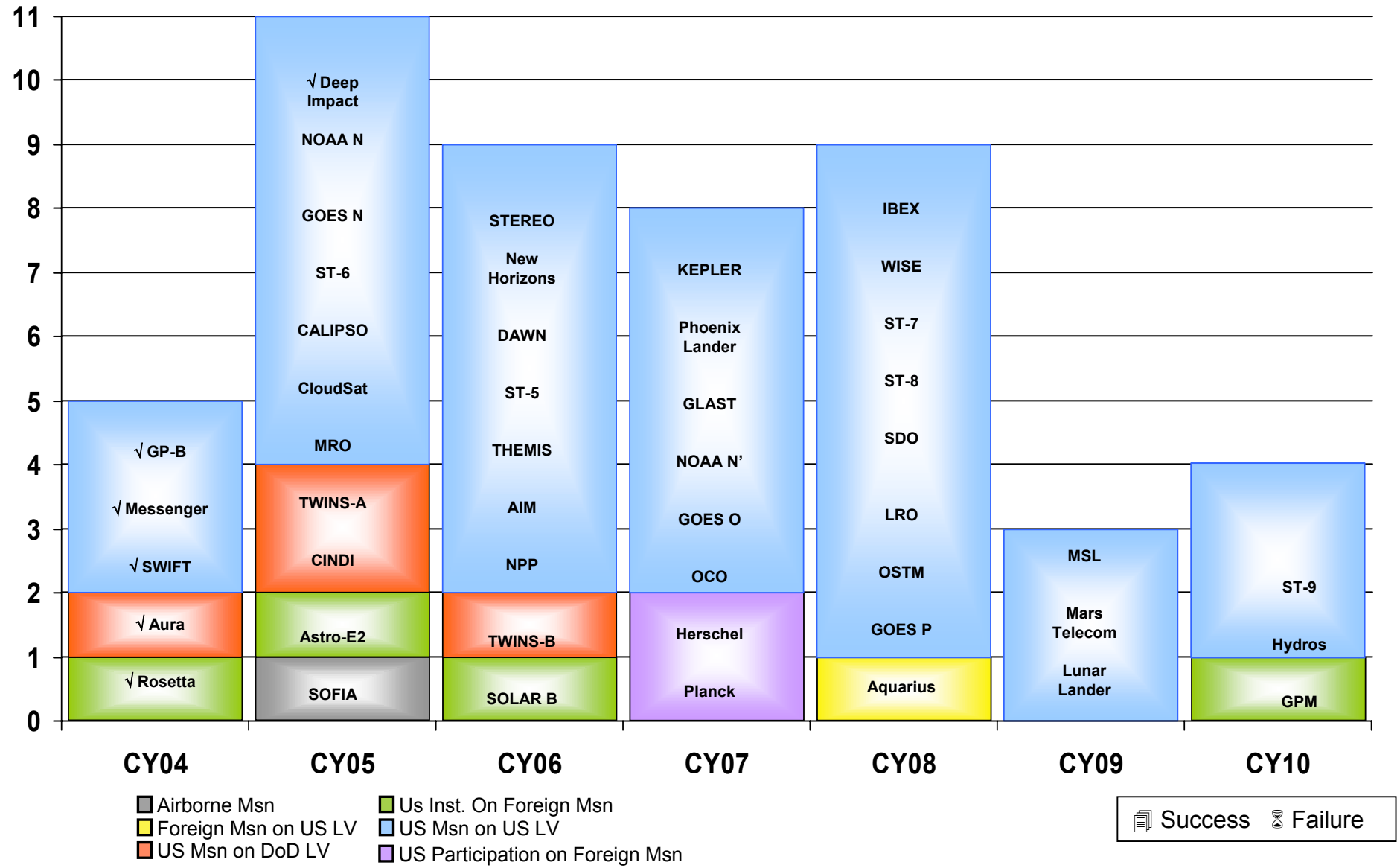
Ranking based on report of the 2003 SEC Senior Review

Impact of Budget Cut

Mission	Current Termination Date	Estimated Termination Date[1]	Remark
SAMPEX	6/2004	6/2004	**terminating on July 1, 2004**
WIND	9/2009[2]	4/2005	**no backup to ACE**
FAST	9/2006	4/2005	
GEOTAIL	9/2009[2]	4/2006	
TRACE	9/2009[2]	4/2006	
Ulysses	3/2008	4/2006	**will miss 3rd solar perihelion**
Voyager	9/2006	4/2006	
Polar	9/2005	9/2005	**no change to plan**
TIMED	2/2007	4/2006	
ACE	9/2009[2]	9/2009[2]	no change to plan
IMAGE	9/2009[2]	9/2009[2]	no change to plan
SOHO	9/2008	9/2008	no change to plan
Cluster	2/2006[3]	2/2006	**extension future in doubt**
RHESSI	9/2009[2]	9/2009[2]	no change to plan

(1) Termination denotes ending mission operations prior to end of science funding
(2) These are carried to the end of the 5-year budget plan
(3) ESA's funding for Cluster ends Dec 2005

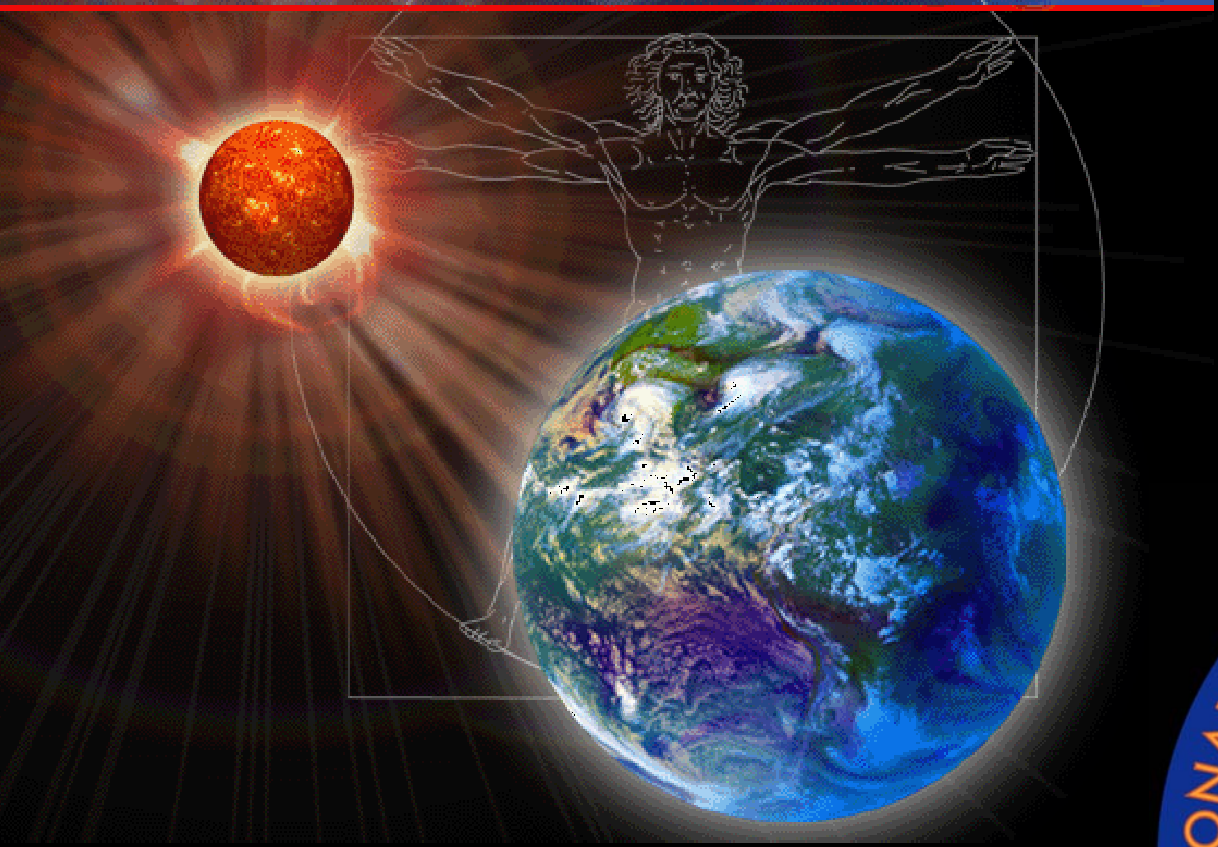
NASA Science Launches (CY04-CY10)



Sun-Solar System Connection

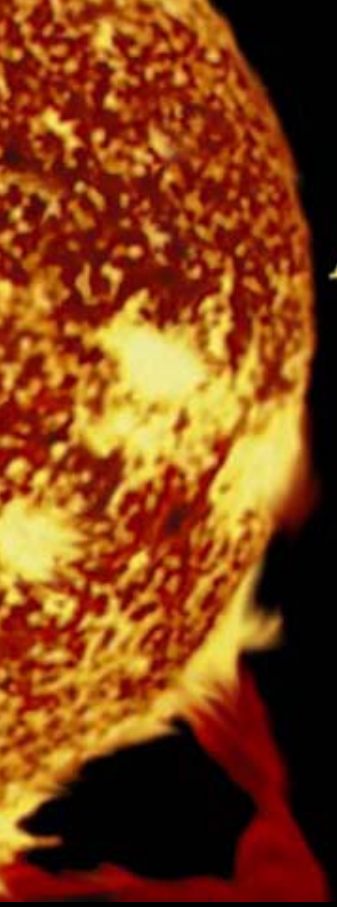
International Workshop

International Living With a Star



- International Living with a Star
- International Heliophysical Year

Opportunities for International Collaboration on Space Weather Research



International Space Environment Service

New Challenges for International Collaboration on Space Weather Forecasting

- **International Space Environment Service**
- **NOAA / World Warning Agency in Boulder, CO**

The world's real-time space weather services are provided by the 10 Regional Warning Centers of the ISES.

These international centers monitor and predict solar-terrestrial activity and provide space weather forecasts and warnings for users who plan or conduct activities sensitive to solar terrestrial conditions

Session 2: Perceptions for Future Potential Collaborative Efforts

- Specific opportunities identified by the breakout group:
- Concept of contemporaneous operation heliospheric of missions such as, ESA/Solar Orbiter, NASA Living With a Star (LWS) Sentinels, and JAXA/L5 .
- Concept of collaborative flight missions in the area of inner magnetospheric research such as CSA/Orbitals and NASA/LWS Geospace space physics missions
- Concepts for collaboration with various heliospheric and magnetospheric single- and multi-spacecraft missions operated by national space agencies.
- Utilization of existing ground stations, facilities, and networks for important collaborative science in conjunction with future space flight missions. This was highlighted by the identification of existing technology, theory, modeling, and instrument development groups represented by the contributors.

Session 2: Key Milestones

- March 2005 - NASA Sun-Solar System Connection (SSSC) Roadmapping 2nd Meeting
- March 2005 - Begin Discussions with ESA on Future Bilateral Meeting on ESA/Solar Orbiter and NASA/LWS Solar Sentinels
- April 2005 - NASA SSSC Roadmapping Interim Report to U.S.
- National Research Council (NRC)
- April 2005 - International Living With a Star meeting, Vienna, Austria
- April 2005 - ESA/NASA bilateral on SOLO/SS
- May 2005 - NASA SSSC Roadmapping Final Meeting
- - 2005 Joint Assembly at New Orleans
- June 2005 - NASA SSSC Roadmapping Final Report to NRC
- June 2005 - ESA/NASA bilateral
- August 2005 - U.S. NRC Review Complete

- Coordination of potential partnerships on future SSSC missions is essential as we finalize mission roadmaps and strategies.


NASA


THAT'S ONE SMALL EEE-O-OOCH!
STEP FOR @☆%#!!... MAN... AND
ONE GIANT YOWW-CHEE-MAMA!
FIRST MAN on the SUN...
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